INDIAN OCEAN YELLOWFIN TUNA SS3 MODEL PROJECTIONS

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Executive Summary

This document presents the projections and Kobe II Strategy Matrix (K2SM) for the 2021 Indian Ocean yellowfin Stock Synthesis assessment model. Deterministic projections for 2021-2030 were conducted for the 96 reference grid scenarios assuming a constant level of catch at 60%-120% of the 2020 catch. The projections incorporate the range of uncertainty among alternative model structures but do not describe uncertainty due to parameter estimation error or stochastic future recruitment variability.

The present projections incorporate an explicit recruitment bias adjustment to avoid the likely overly optimistic results as identified by the Working Party on Tropical Tunas during the 23rd WPTT Stock Assessment meeting (WPTT, 2021, paragraph 125), if no explicit bias adjustment controls are used in the forecast. Also, as requested at the WPTT 23rd Stock Assessment meeting, we examine the effects of bias correction on the projection outputs.

1. Introduction

At the 23rd IOTC Working Party on Tropical tuna (WPTT), a preliminary stock assessment for yellowfin tuna (Thunnus albacares) in the Indian Ocean was presented (Fu et al, 2021). The assessment was implemented using the Stock Synthesis software with the inclusion of fishery data up to 2020 (final model year). The WPTT agreed to adopt a reference grid of 96 models to capture major sources of uncertainty and to assist the formulation of help formulate management advice (IOTC–WPTT23 2021). The model grid incorporated alternative spatial configurations (2), levels of steepness (3), hypotheses on catchability (2), growth (2) and natural mortality (2), and tag data weighting (2). The overall stock status is estimated to be overfished (average SSB/SSBmsy=0.78) and subject to overfishing (F/Fmsy=1.27).

During the meeting, the WPTT noted that the assessment model adopted the default SS3 bias adjustment control settings such that a full recruitment bias correction is implemented in the model period but no correction is applied in the forecast. This is likely to cause the projection to be overly optimistic. Subsequently, the WPTT decided that the SS3 projections would be conducted intersessionally to develop the K2SM to provide management advice. This document summaries the results of the projections based on the final model grid. The projection implemented the optimal bias correction adjustment (instead of the full bias correction as in the current assessment model) as recommended by Stock Synthesis. The bias correction was applied to both model and projection period consistently.

2. Methods

Recruitment bias adjustment

Recruitment (fish at age 0) in Stock Synthesis is generated from the stock-recruitment relationship as modulated by recruitment deviations, which are assumed to be lognormally distributed. The SS also used a procedure called recruitment bias correction to ensure that on average the recruitment did not deviate significantly from the stock-recruitment relationship (this requires the average bias-corrected recruitment deviations to tend to approach 1). This process is important to ensure that the average recruitment estimate is unbiased, while taking into account recruitment variability. By default, SS3 uses a full bias correction equal to $-\frac{1}{2}\sigma^2$, based on the distributional assumption for recruitment deviations (σ is the standard deviation of the lognormal distribution). This is the option previously used in the assessments of IOTC yellowfin tuna (Langley 2015, 2016, Fu 2018). However, during the 23rd WPTT meeting it was noted that the default bias correction settings are not automatically extended to the forecast period, resulting in a discontinuity in recruitment in the forecast. This suggests that the predictions made by previous assessments are likely to be overly optimistic (in terms of K2SM probabilities). Therefore, the configurations of the 2020 assessment have been adjusted so that bias correction also applies to the forecast period.

Further, Methot and Taylor (2011) show that the estimated recruitment variability is always smaller than the true recruitment variability (σ^2), because the data included in the assessment model are not perfectly informative of recruitment. They recommended that the optimal bias correction should be less than the full bias correction as adopted in the default setting. Methot and Taylor (2011) implemented a method that iteratively estimate the true variability among recruitments so that the optimal bias correction adjustment ($-\frac{1}{2}b\sigma^2$) can be determined, where $b \leq 1$ can be calculated from the data. In this approach, bias correction is applied only to recruitment deviations that have sufficient data to provide information about the full range of recruitment variability. Optimal bias correction is considered a better method and is currently implemented in SS3's advanced model settings, although this approach is unlikely to have a significant impact on biomass estimation (the bias correction is effectively a constant offset through the time series which can be compensated by the estimates of R0 parameters). The sections below examine in more details the effect of different bias correction on the projection.

The default settings of the original model implemented full bias correction, which is much larger than the optimal correction estimated from the data through the function "*SS_fitbiasramp*" available in the r4ss R package (Figures 1). Because the bias correction was not applied during the forecast period, it caused a relatively large change in the average recruitment of the forecast (Figure 2). The model is then reconfigured with the optimal bias compensation settings. This is estimated to be about 60% of the full bias correction. Bias correction is also extended to the forecast period (Figure 3). Figure 4 shows that if the original model is projected forward (with current catch), even if the current fishing mortality is higher than Fmsy, the stock would start to recover quickly due to high recruitment. In contrast, when the bias is also adjusted in the forecasting period, current catches would exacerbate stock decline as expected.

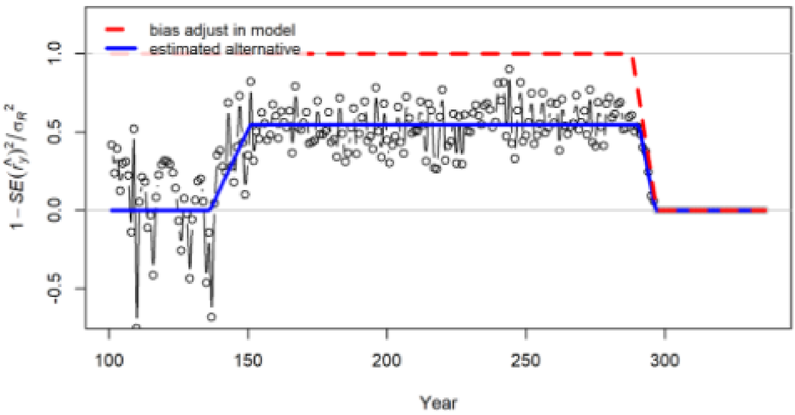


Figure 1. Red line shows the original settings for lognormal bias adjustment in recruitment deviations. The red line shows the default bias adjustment originally applied, while the blue line shows the appropriate level of bias adjustment, as estimated by r4ss. The difference between the red and blue trajectories explains the jump at the beginning of the projection period (Year 298) based on the default assumption about lognormal recruitment bias. At this point, the bias is removed and the projections are made with more recruits than were estimated during the model fit.

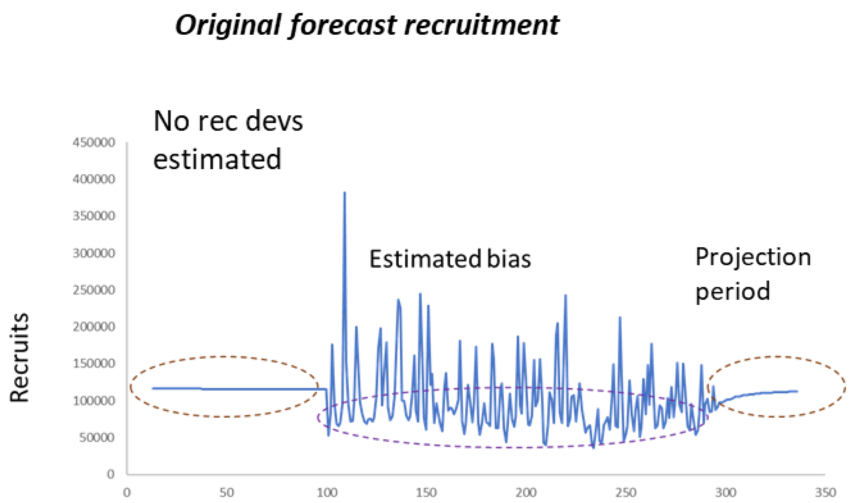


Figure 2. Recruitments in the three model periods. The model estimates recruitments during the model fit period, which are then used to estimate the appropriate level of lognormal bias adjustment. Bias adjustment is not applied in the forecast period.

New (correct) forecast recruitment

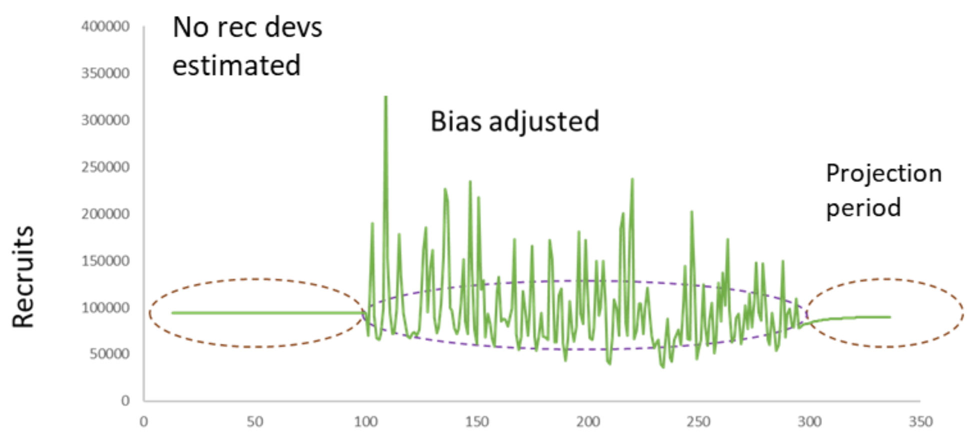


Figure 3. In the bias adjusted (corrected) forecast configuration there is no bias of recruitment across periods (fit and forecast).

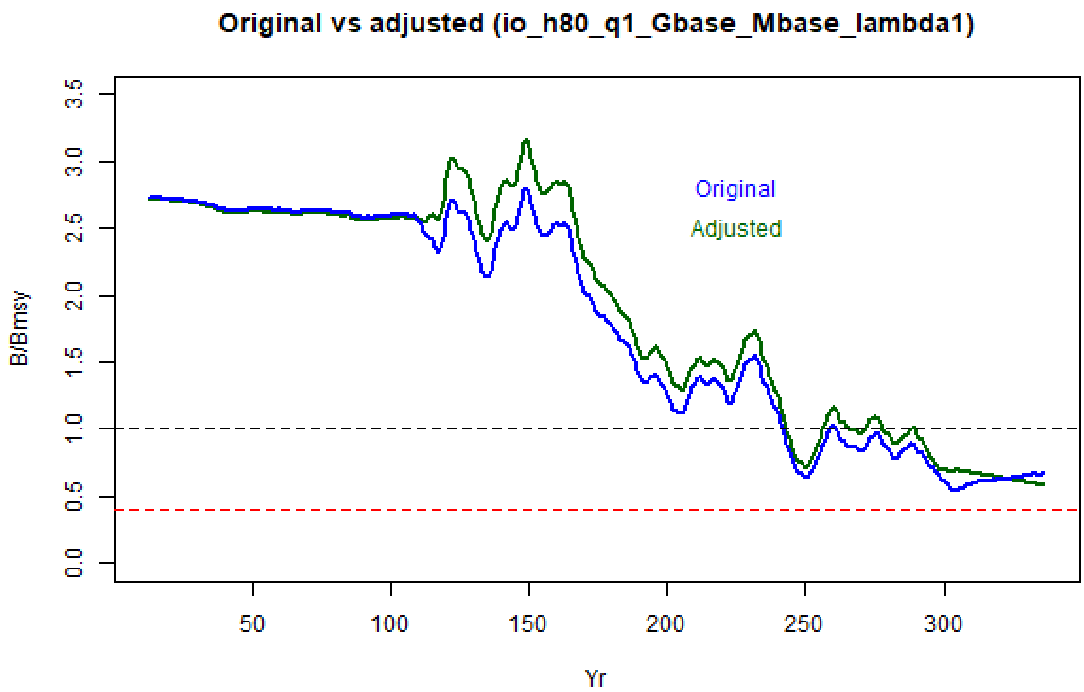


Figure 4. Comparison of relative biomass projections of current catch with bias correction (green) and bias not adjusted (blue).

Projections set-up

Projections were conducted for a 10-year period (2021–2030) from the Maximum Posterior Density (MPD) estimates of all grid models at a constant level of catch as a multiple of the fishery catches in 2020. Seven levels of catch were investigated representing 60% to 120% of the 2020 catch level (in increments of 10%). The catch allocations among fisheries were based on the catch shares in 2020 amongst fleets defined in the SS3 model. The projections used deterministic recruitment from the stock recruitment relationship. The Kobe2 Strategy Matrix probabilities were calculated from the 96 reference grid scenarios. For each catch scenario, the probability of the biomass being below the target and limit reference points (SSB_{MSY} and $0.4xSSB_{MSY}$ respectively) and the probability of fishing mortality being above the target and limit reference points (F_{MSY} and $1.4F_{MSY}$) were determined over the projection horizon using the delta-MVLN estimator (Walter & Winker 2019), based on the variance-covariance derived from estimates of SB/SB_{MSY} (or $SB/0.4SB_{MSY}$) and F/F_{MSY} (or $F/1.4F_{MSY}$) across the model grid.

3. Results and discussion

The results of projections of the 96 grid SS3.30 models are provided in the form of probabilities that $F > F_{MSY}$, $SSB < SSB_{MSY}$ and $F > F_{Lim}$, $SSB < SSB_{Lim}$ in a K2SM framework (Table 1) and relative biomass and fishing mortality trends (Figures 5, 6 and 7). The projections indicate the levels of catch and their associated probability for the stock to be overfished (B<Bmsy), subject to overfishing (F>Fmsy) and the probability of violating limit reference points (B<Blim and F>Flim) in 2023 and 2030 (Table 1).

TABLE 1. Yellowfin tuna: Stock synthesis assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for constant catch projections (relative to the catch level from 2020 -40%, - 30%, -20%, -15%, -10%, ± 10%, +20%) projected for 3 and 10 years.

Alternative catch projections (relative to the catch level from 2020) and probability (%) of violating MSY-based target reference points ($B_{targ} = B_{MSY}$; $F_{targ} = F_{MSY}$)							
Reference point and projection timeframe	60%	70%	80%	90%	100%	110%	120%
$B_{2023} < B_{MSY}$	0.45	0.56	0.68	0.74	0.76	0.82	0.88
$F_{2023} > F_{MSY}$	0.13	0.30	0.53	0.63	0.72	0.82	0.91
$B_{2030} < B_{MSY}$	0.1	0.33	0.54	0.76	0.93	0.99	1

$F_{2030} > F_{MSY}$	0.07	0.31	0.49	0.69	0.84	0.97	0.99
Alternative catch projections (relative to the catch level from 2020) and probability (%) of violating MSY-based limit reference points ($B_{lim} = 0.4\ B_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)							
Reference point and projection timeframe	60%	70%	80%	90%	100%	110%	120%
$B_{2023} < B_{Lim}$	0	0	0	0.05	0.07	0.1	0.16
$F_{2023} > F_{Lim}$	0.03	0.11	0.25	0.43	0.52	0.63	0.78
$B_{2030} < B_{Lim}$	0	0	0.01	0.18	0.64	1	1
$F_{2030} > F_{Lim}$	0.02	0.19	0.33	0.60	0.78	0.98	0.98

According to the K2SM the stock would only recover to levels above Bmsy by 2023 if catches are reduced 40% from current levels. In order to recover the stock to levels above Bmsy by 2030 with 50% probability or more, current catch would need to be reduced by more than 20%. In order to reduce overfishing (F<Fmsy) by 2023, levels would need to reduce more than 20% from current levels and to achieve this by 2030, catches would need to reduce by 20%. The probability of breaching the biological limit reference point with current catches is 7% by 2023 and 64% by 2030. The probability of breaching the F limit reference point with current catch is 52% by 2023 and 78% by 2030.

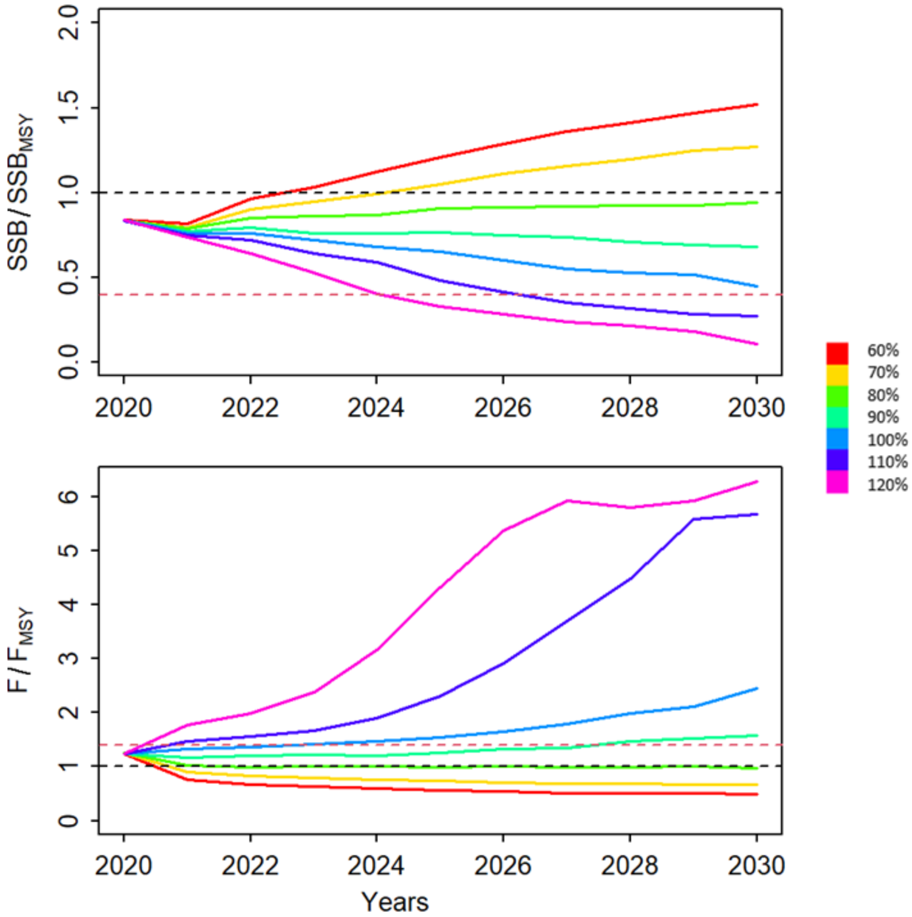


Figure 5. Average trajectories of relative biomass (SSB/SSBmsy) and fishing mortality (F/Fmsy) for the seven levels of catch used in the projections

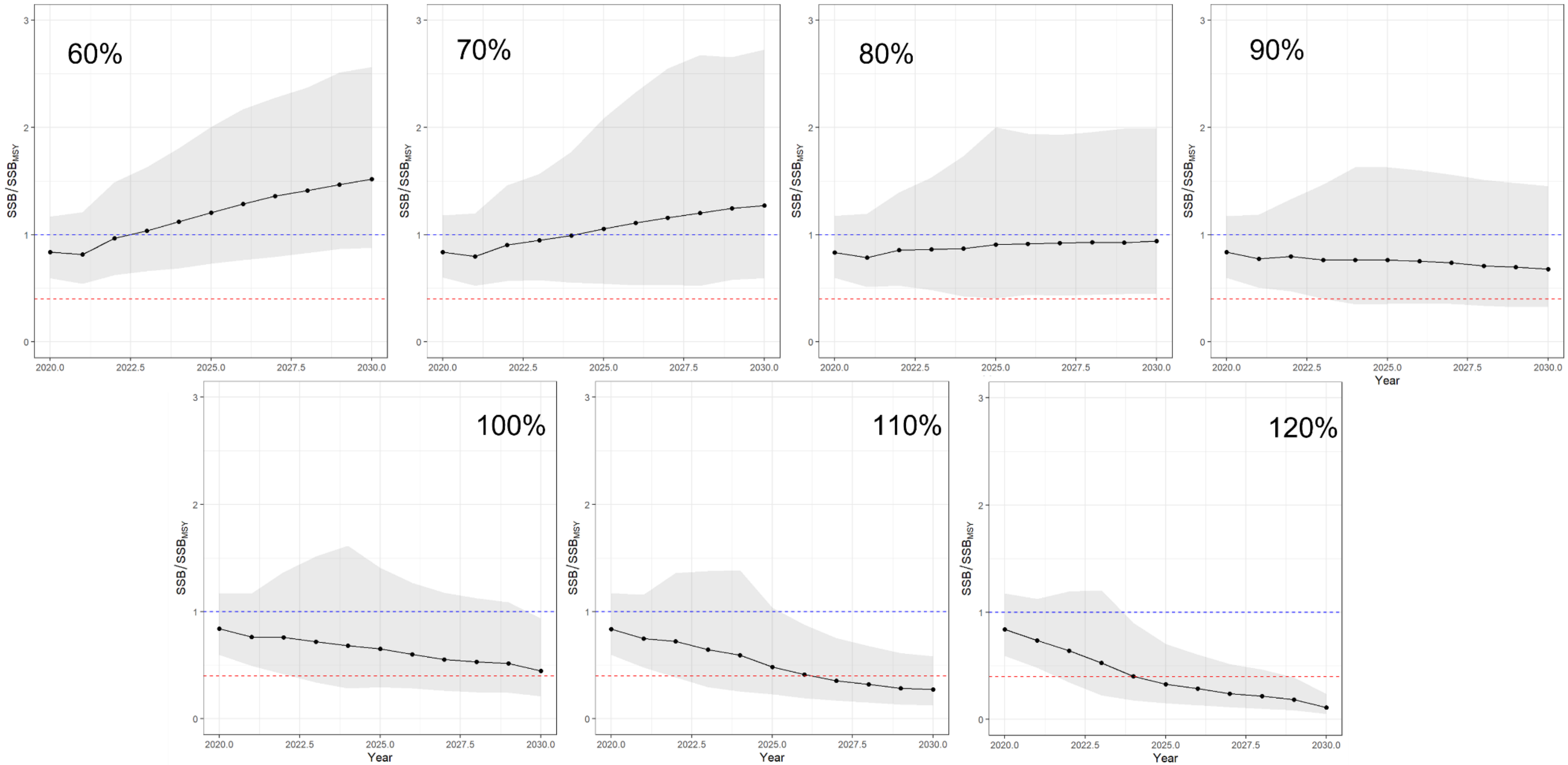
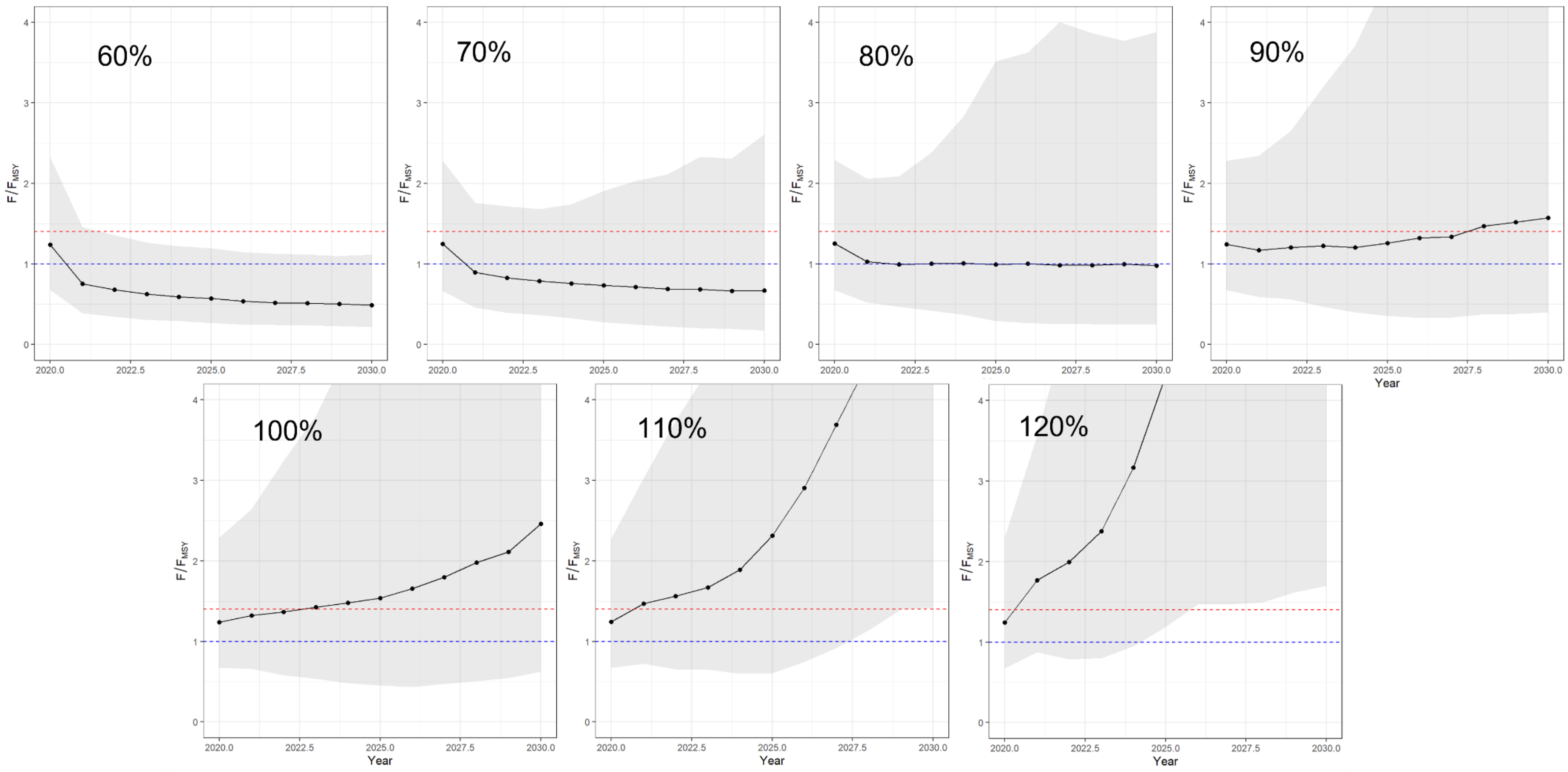


Figure 6. Trend of relative biomass (SSB/SSBmsy) for the seven projections, each with a level of reduction from 2020 catch, showing the average trajectory (black dotted line) and 90% confidence interval (gray shadow).

Figure 7. Trend of relative fishing mortality (F/Fmsy) for the seven projections, each with a level of reduction from 2020 catch, showing the average trajectory (black dotted line) and 90% confidence interval (gray shadow).



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